Space Technology Research Grants

Complementary Flyover and Surface Exploration of Planetary Destinations Where 3D Detail Matters

Completed Technology Project (2012 - 2016)

Project Introduction

Points of persistent light exist on the rim of Shackleton crater and at other polar locations on the Moon, and perhaps Mercury. These destinations could serve as bases of operations or power stations for exploitation of polar resources. While sunlight is not truly eternal at these sites, the periods of illumination are much longer than elsewhere on the Moon. Solar-powered robots can explore these locations, hibernating through the short periods of darkness or moving from one oasis of light to another. But, for polar destinations, even small rocks cast long shadows, and unexpected shadows can be mission-ending for small rovers. Precise knowledge of 3D structure on the meter-scale and smaller is needed to predict where shadows will fall. Sub-surface caverns may be the best place on Mars to find life. They may be the best hope for human habitation on the Moon. They can serve as safe havens that shield robots, astronauts, and structures from radiation, micrometeorites, dust storms, and temperature extremes. They also provide windows into a planet's past geology, climate, and even biology. Skylights, formed by partial cave ceiling collapse, provide access to sub-surface voids. They have been conclusively shown to exist on Mars and the Moon, and evidence supports their existence on other planetary bodies throughout the solar system. Because skylights are so new and so unknown, it is much too risky to send astronauts, or even complex and expensive robotic systems, to explore these holes and the caverns below without prior reconnaissance. Surface robots can approach a skylight and scan the walls, but skylight geometry prevents viewing the floor of the hole from a surface perspective. This research proposes complementary flyover and surface exploration for reconnaissance of point destinations, like skylights and polar crater rims, where local 3D detail matters. This reconnaissance is different from previous approaches to planetary exploration: it must detail the geometry of high-relief point targets partially obscured by terrain, not simply characterize regions. Lander flyover captures detailed overview data, as well as perspectives that cannot be observed from a rover viewpoint. Rovers can capture close-up images of the terrain, and they can linger to capture multiple views from stationary locations, though always from low, grazing perspectives. Alternately, landers can acquire bird's-eye views but with less detail and resolution since their one-pass, always-moving trajectories are constrained by fuel limitations. Lander and rover data are combined, using lander data to localize and plan rover paths, to autonomously construct quality 3D models of point destinations. Both cameras and active sensors, such as LIDAR (LIght Detection And Ranging), are used for model construction in the proposed approach. Active sensing is needed to peer into shadowed regions, but active sensors do not have the resolution that can be achieved with cameras and are range-limited by available power. Camera and LIDAR data are fused into high-fidelity models, but the real value in having both data types comes when localizing rovers within maps built from lander data. Difference in perspective between rover and flyover (lander or orbiter) data has traditionally been a stumbling block for automation of rover localization. This research proposes to solve the

Project Image Complementary Flyover and Surface Exploration of Planetary Destinations Where 3D Detail Matters

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

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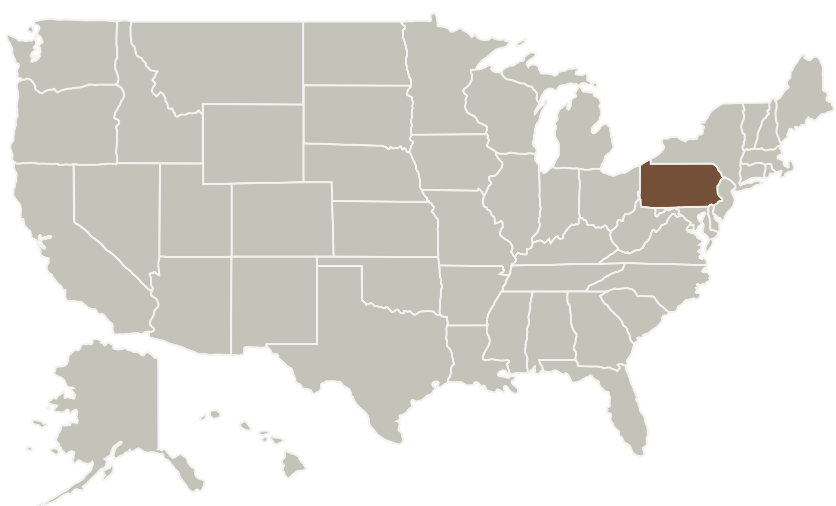
problem by taking full advantage of 3D and visual data, both in maps and in rover data. Approaches using both 3D and visual features simultaneously will be explored, as well as approaches that use one data type for coarse localization and another for refinement. To facilitate exploration even in communications-limited areas, and to increase the efficiency with which exploration operations are performed, a fully autonomous modeling approach is proposed. Rover paths and views are planned autonomously, using next-best-view concepts, to fill holes and investigate areas of interest within a lander model.

Anticipated Benefits

Sub-surface caverns may be the best place on Mars to find life. They may be the best hope for human habitation on the Moon. They can serve as safe havens that shield robots, astronauts, and structures from radiation, micrometeorites, dust storms, and temperature extremes. They also provide windows into a planet's past geology, climate, and even biology. Skylights, formed by partial cave ceiling collapse, provide access to sub-surface voids. They have been conclusively shown to exist on Mars and the Moon, and evidence supports their existence on other planetary bodies throughout the solar system. Because skylights are so new and so unknown, it is much too risky to send astronauts, or even complex and expensive robotic systems, to explore these holes and the caverns below without prior reconnaissance. Surface robots can approach a skylight and scan the walls, but skylight geometry prevents viewing the floor of the hole from a surface perspective.

Primary U.S. Work Locations and Key Partners



Project Management

Program Director:
Claudia M Meyer

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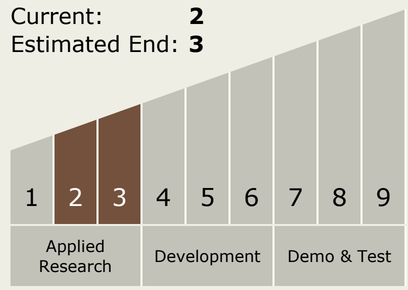
Hung D Nguyen

Principal Investigator:
William Whittaker

Co-Investigator:
Heather L Jones

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX10 Autonomous Systems
  └ TX10.1 Situational and Self Awareness
    └ TX10.1.3 Knowledge and Model Building

Primary U.S. Work Locations

Pennsylvania

Images

11494-1363117066815.jpg
Project Image Complementary Flyover and Surface Exploration of Planetary Destinations Where 3D Detail Matters
(https://techport.nasa.gov/image/1729)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html